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Accretion Events in Binary Systems: AZ Cas and VV Cep

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Abstract. The sudden lengthening of orbital period of VV Cep eclipsing binary by about 1% was observed in the last epoch. The mass transfer and/or mass loss are most possible explanations of this event. The photometric behaviour of AZ Cas, the cousin of VV Cep, suggests that the accretion can occur and could be important in this system, too.

Introduction

AZ Cas and VV Cep are eclipsing binary stars with one of the longest orbital periods (9.3 and 20.3 years, respectively). They both belong to VV Cep type-systems, consisting of a M or late K supergiant and an early B star, and have spectra exhibiting strong Balmer and $[FeII]$ emission lines (Cowley 1969). The presence of an intensive mass loss gives us an opportunity to study the accretion processes. The most recent, 1997 eclipse of VV Cep occurred by about 1% of the orbital period later than predicted (Graczyk et al. 1999), perhaps as a result of mass loss and/or mass transfer. The behaviour of both systems seems to have the same cause, connected with strong interactions between the components close to periastron phase and it can influence on times of minima due to changes in the orbital parameters.

Observations of the last eclipses

Multicolor photometry of the last AZ Cas eclipse was obtained with a 60 cm reflector at Piwnice Observatory (Poland). Our $UBVR$ light curves are presented in the Figure 1 (top) phased together with photometric data from other observatories. Our BVR photometry after the eclipse shows an increase of the brightness by a few % of magnitude during ~ 250 days. This effect was commented by Tempesti (1980), and as a first approximation it can be interpreted as effect of tidal distortion of the cool component surface around the periastron. Nevertheless, our observations are made also in phases which have never been covered with multicolor photometry before. For example, the long atmospheric

eclipse in U bandpass (up to ~ 0.1 phase) seems to indicate, that the cool component is surrounded by an extended envelope formed by its own stellar wind. The hot component could accrete gas from the wind and the matter transferred through the L_1 point by the cool giant Roche lobe overflow near the periastron. In the out of eclipse data (the phase range from ~ 0.25 to ~ 0.45) we have observed very interesting variability with smallest amplitude in V bandpass, and much stronger in the U and in $U-B$ color index. The color indices evolution (Figure 1–inner box) can not be explained at this time, and we can only assume, that this is connected with accretion of material which was lost by supergiant near the periastron passage and with cooling of supergiant atmosphere.

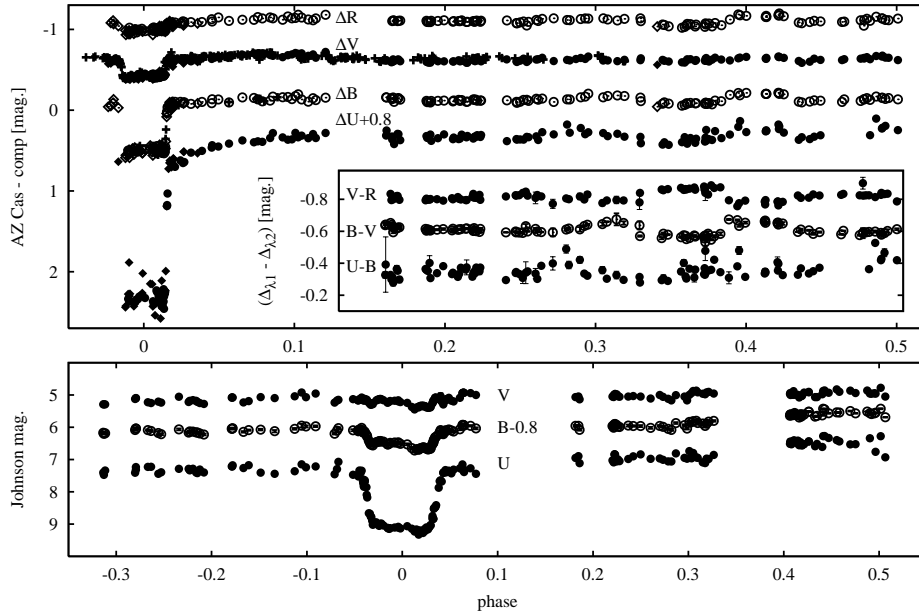


Figure 1. $UBVR$ light curves of AZ Cas (top). Circles: Piwnice Observatory data points. Diamonds: Suhora and Cracow measurements (Mikołajewski et al. 2004). Crosses: Larsson–Leander (1959) and Tempesti (1980) data. Changes of the $U-B$, $B-V$ and $V-R$ color indices of AZ Cas (top–inner box). UBV light curves of VV Cep (bottom).

The VV Cep system has been observed in Piwnice Observatory for ~ 17 years. The collected UBV light curves are presented in the Figure 1 (bottom panel). Especially strong variations in the U bandpass can be attributed to mass accretion on the hot component, as they disappear during the eclipse. The delay of the last eclipse event could occur, as the result of changes in orbital parameters (perhaps e and ω) due to interaction and mass loss/transfer near the periastron passage in the previous epoch.

AZ Cas spectral type changes

Méndez et al. (1975) suggested that the spectral type of the cool component can vary with the orbital phase. Around the periastron phases, the cool component

can look like a K supergiant (e.g.: K3.8Ib/Iab (Wawrukiewicz & Lee 1974)) and perhaps even close to F type during the eclipse (F8Ib (Méndez et al. 1975)). In most cases the cool component is classified as M type supergiant (e.g.: M0Ib (Lee 1970)). We used a Coude spectrograph at the Rozhen Observatory (Bulgaria) to obtain spectra of AZ Cas in totality in 2003, and echelle spectrograph at the Asiago Observatory (Italy) to obtain one spectrum near the periastron in 2004. In Figure 2 our spectra are compared with the spectra of HD 11800 (K5Ib) and HD 12014 (K0Ib) taken from the library of Montes et al. (1999).

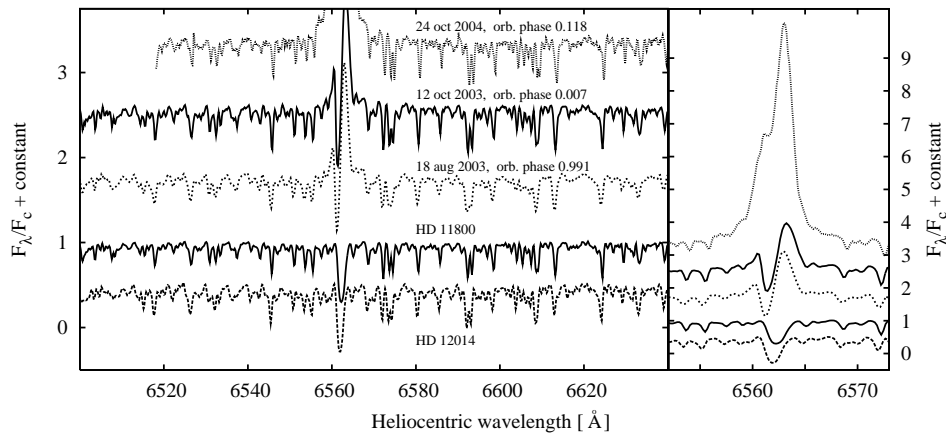


Figure 2. The Rozhen and Asiago spectra of AZ Cas ($R \sim 16000$) compared with the spectra of HD 11800 (K5Ib) and HD 12014 (K0Ib).

In our spectra the cool component looks like an early K type supergiant. During the totality there is seen H_α emission with superimposed absorption (Figure 2: right) whereas the H_β emission is absent. H_α emission seems to be especially strong close to the periastron. In Figure 3 (left panel) the U - B , B - V color-color diagram is presented. The reddenings for the hot and the cool components are different and E_{B-V} have values 0.90 ± 0.11 and 0.64 ± 0.22 respectively, which cause an impression that cool component could be somewhat more blue at the eclipse, possibly as a result of an excess of radiation in short wavelengths. During totality, the supergiant looks like K0–2 type star.

Ellipsoidal and scattering effects in AZ Cas

A model resulting from the Wilson & Devinney (1971) code, adopting Cowley et al. (1977) orbital parameters $e = 0.55$, $\omega = 4^\circ$, can explain quite well the brightening of the system near the periastron as a result of the ellipsoidal effect. However there is a visible excess of radiation near and during the eclipse (Figure 3–right panel), which could be produced by a scattering of radiation emitted by the hot component in the very extended envelope of the supergiant. Such effect could also explain the brightening observed in the mid-eclipse phase (see Figure 1).

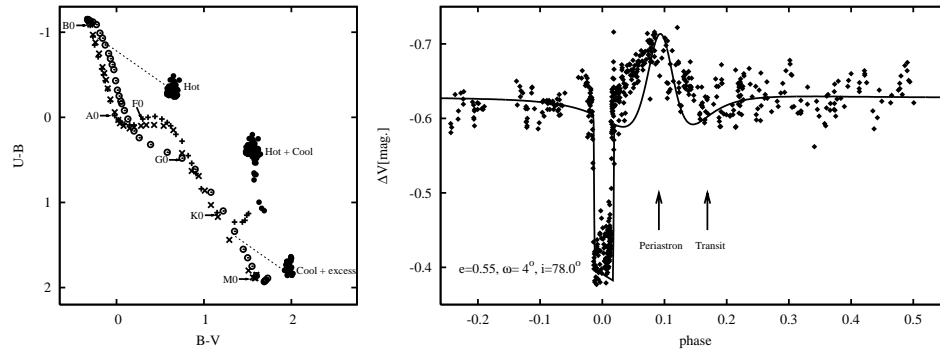


Figure 3. On the left $U-B$, $B-V$ color-color diagram is presented, where the position of the system during the eclipse (Cool + excess), out of eclipse (Hot + Cool), and only hot component extracted (Hot) are shown. Straižys calibrations are drawn with symbols +, \times , \odot for V , III and I luminosity class respectively. On the right the synthetic V light curve is compared with the observational data.

Conclusions

1. Both systems show flux changes in hot component near and after the periastron passage.
2. The cool component is surrounded by an extended envelope, because:
 - a. broad atmospheric eclipse in U bandpass is visible,
 - b. the color of the cool component is more blue during the eclipse (scattering of the hot component light in the supergiant envelope),
 - c. the absorption component in H_{α} appears during the eclipse.
3. Mass loss/transfer leads to changes of the orbital parameters (e , T_o , ω , i , P) and not only in the orbital period as it was suggested by Graczyk & Mikołajewski (2001).

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